Neuropsych

Computers in Psychology

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Methods, Instrumentation and Psychodiagnostics

NEUROPSYCH: Computer-assisted neuropsychological assessment

N. Brand[1] and J. Jolles[2]

Abstract

Assessment of the exact nature and degree of cognitive deficits in individual patients requires sophisticated and refined measurements. In order to investigate the potential value of computer based assessment, a stimulus-response system called NEUROPSYCH was developed and implemented on a microcomputer. It allows for control of slide projectors, video graphics and other visual signals, and registration of latencies by way of several exchangeable keypads. The software consists of assembler-routines, which can be called from BASIC. The tasks that have been developed for this system are derived from theoretically well defined paradigms. They consist of verbal and nonverbal memory-tests, and motor tasks. Also, a test has been implemented on an XY-tablet, thereby combining the advantages of paper and pencil tests with those of the computer. Two tests are discussed and some results of current research shown. NEUROPSYCH may provide an efficient and refined way of measurement. Better insight into cognitive dysfunctions might be gained when this methodology is combined with other neuropsychological assessment techniques.

1. Introduction

Neuropsychological assessment involves the measurements of cognitive functions, such as perception, motor functions, language, planning and behavioral organization, and memory. An extensive collection of diagnostic instruments (e.g. psychological tests) is needed for this end. In addition, the use of a good model of brain-behavior relationships is of importance in this respect. The neuropsychologist thus tries to arrive at valid conclusions about the cognitive functions and dysfunctions of the patient under study.

The methodology that is traditionally used in evaluating the cognitive 'state' - mostly standardized psychometric tests - has some major draw-backs in neuropsychological assessment (Jolles, 1985). The well known advantages are that these tests are standardized and that published norms are generally available. They are easy to administer and there is usually a high reliability. The drawbacks are that most psychometric tests are not sensitive and reliable enough to be used in the assessment of particular subjects. This applies especially to the relatively mild cases. Also, the traditionally used tests do not enable the identification of the cognitive deficits that underlie the testscores: they measure performance, not cognitive functions (Jolles, 1985).

The information-processing approach, if combined with other quantitative and qualitative measures, may provide a better methodology in this respect (Poon, 1983; Jolles, 1985). This approach may be advantageous in the assessment of many cognitive functions because of the refined methods of stimulus presentation and recording of responses and reaction times (RT). Use of the computer for these matters and the use of theoretically well defined information processing tasks may thus provide an important contribution to neuropsychological assessment.

Many neurological and psychiatric patients show cognitive deficits (e.g. Glass, Uhlenhuth, Hartel, Matuzas & Fischman, 1981; Brand & Jolles, 1987). The exact nature and degree of these dysfunctions is not clear: psychologists complain about their grip on the cognitive differentiation of psychiatric patients. It is of importance to establish that much research with information processing tasks has been spent on differences between groups. This applies for instance to the use of the Sternberg paradigm (1975) in the clinic. An example of the use of this paradigm in the clinic is found in Brand and Jolles (1987) in which patients with affective disorders could be discerned by the use of information processing tasks. Unfortunately, little is known about the value

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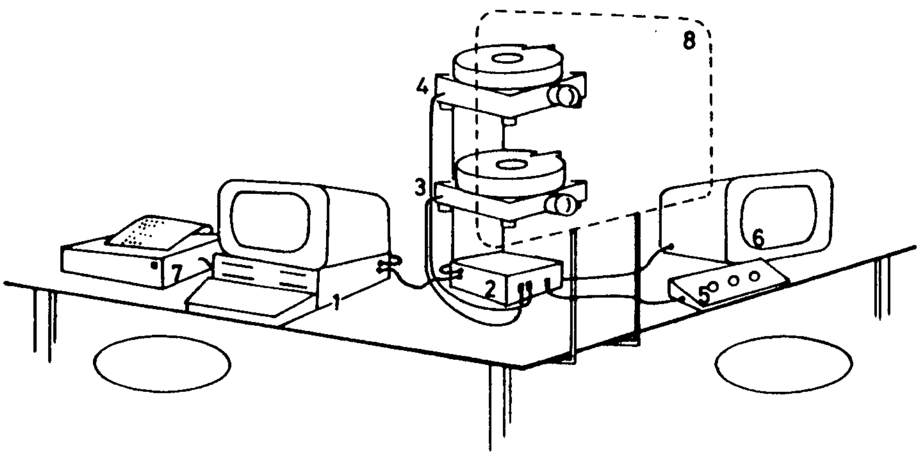

Figure 1. NEUROPSYCH: hardware configuration. See text.

of information processing tasks for the individual subject, although it has been stated repeatedly that these tasks generally seem too difficult or too long for the individual patient.

The present study describes the development of a computer-aided assessment system and the use of tasks and test programs that meet the requirements for application in the clinic. As the tasks have to be simple and relevant for the patient the program should be user friendly and allow easy manipulation of task parameters by the investigator (psychologist or test assistant).

2. *NEUROPSYCH: system description*

2.1. *Boundary conditions*

In the development of a system based upon personal computer methodology the following conditions were regarded as important.

- It should allow the (tachistoscopical) presentation of stimuli both via the monitor and via slide projector.
- It should allow measurement of reaction times (RT) up to the nearest ms.
- It should have ready-made routines in order to allow easy development of new tasks and tests by a psychologist with little programming experience.
- It should be possible to measure the RT via exchangeable keypads with different arrangements of keys.

The test programs should meet the following requirements:

- They should be installed and run easily by the psychologist or experimenter.
- They should be simple, comprehensible and 'proof' for even highly disturbed patients.
- It should be easy for the investigator to change parameter values in a test.

2.2. *Hardware*

A hardware and software system called NEUROPSYCH was developed and implemented on a BASIS 108 (Apple-compatible) 8-bits microcomputer. Figure 1 is a sketch of the set-up. The system was developed in collaboration with H. Essers from the instrumental department of the AZU. The microcomputer (1) is connected with a parallel interface (2) which allows for control of two slide-projectors (3,4) which are supplied with mechanical shutters (Compur). This enables tachistoscopic presentation of stimuli on a back-projection screen (8). Projectors are installed in a sound-attenuating little room (not shown). Video graphics and other visual signals such as LED-buttons (7), are controlled in the same way. Stimulus material and test instructions to the subject may be displayed on a second (RGB) computer screen (6). The interface also takes care of registration of responses and latencies (up to the nearest millisecond), by way of several exchangeable keypads (5). A maximum of 8 keys may be read simultaneously. Test results can be sent to a printer (7).

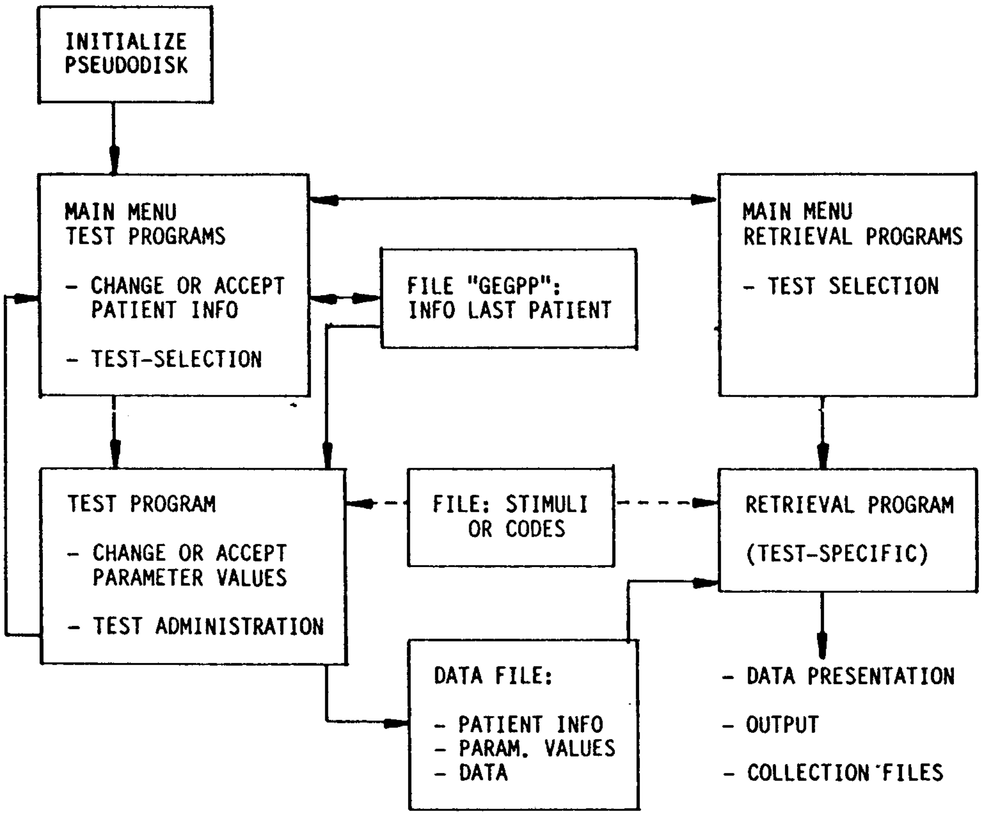

Figure 2. NEUROPSYCH: organization and program-structure.

2.3. *Software*

Control of stimulus events and registration of responses are realized by assembler routines (ampersand functions). These functions can be called quite easily in a standard BASIC program. Seven routines are developed, three of which are meant for handling the slide projectors:

&SWITCH (projnr, on/off)	- turn a projector on or off
&DIASET (projnr, slidenr)	- select and install a slide
&DIASHW (projnr, showtime, mode)	- open the shutter for a particular time and wait until key has been pressed or continue

Figure 2 presents the general organization of the tests and other programs. The NEUROPSYCH software runs under the DOS 3.3. operating system. It is housed on two diskettes, one for test programs and one for 'retrieval' programs (which take care of off-line data processing) and other help programs. Data is written onto a separate data-disk.

The test programs make use of a pseudo-disk (RAM-extension) so that a test program has to be loaded from disk only once. There is a central START-program where information for patient identification is fed in, and from which the tests are selected. A test program tells the investigator first what keypad he should connect and then shows a list of test parameters with default-values. These values define the stimulus duration, the duration of intervals between trials or between a response and the next trial, and the number of trials and practice trials. Test-specific parameters, such as color and the nature of the verbal stimuli on the screen (e.g. upper or lower case), are defined in the same way. Stimuli or event codes are read from data statements or from a separate file.

The test instruction is displayed on the (two) monitors as soon as the parameter values are changed or accepted. The instruction is read aloud by the investigator and the patient may also follow it on his own screen. The experimenter can monitor the test performance on his screen. During the test or at the end some summary statistics are displayed. The data (latencies or specific response codes) are written to a test-specific datafile which also contains patient information and parameter values.

The second program starts with a central menu for selection of a test-specific retrieval program. This program asks for the identification of the patient and reads the data from his or her file. After data processing, some simple statistics are presented such as descriptive statistics and simple linear regression. Some applications allow for the presentation of the individual results in a graph.

Finally, the data from different patients can be collected into a larger file, and processed by a specific statistical package or transferred to a mainframe for other statistical purposes.

2.4. Tests

The neuropsychological tasks that have been developed for this system, are derived from theoretically well-defined paradigms. The tasks that have been realized are:

A. Memory Comparison Task (screen version, Brand & Jolles, 1987; Brand, 1987). This task has been derived from the Sternberg (1975) paradigm and measures certain stages of information processing with verbal material.

B. Memory Comparison Task (XY-tablet version, Houx, Brand & Jolles, 1986).

C. Compatibility test (Brand and Jolles, 1985b). This task relies on the paradigm which measures the stages of motor preparation and motor execution (Fitts, 1954).

D. Tapping test.

E. A visual version of the 15 word learning test (Brand and Jolles, 1985a; Brand, 1987). This task is described below.

F. Facial recognition test (Brand, 1987). This task is described below.

One verbal and one nonverbal memory test of the computer-aided assessment system are outlined briefly in the remainder of this text. Other tests are discussed elsewhere.

3. Application of NEUROPSYCH: a visual word learning task

The 15 word learning task is a multi-trial free recall test which offers a useful paradigm for research into memory processes (Brand and Jolles, 1985a). The test is used clinically for the assessment of memory disorders (Luria, 1976; Deelman, Brouwer, van Zomeren & Saan, 1980). It has been shown (Brand and Jolles, 1985a) that normal volunteers have a similar recall performance on the visual test compared to an auditory version.

Presentation mode seems to be of importance for the recall performance of certain neurological patients (Luria, 1976). Although it has always been an auditory version that has been used in memory research, a visual version may have advantages which have to do with standardization of test administration. We describe here an experiment with the visual version of the task in which the learning ability of depressive patients was compared to that of controls (Brand, 1987).

The visual version of the 15 word test consists of a list of 15 monosyllabic meaningful words which is presented in 5 trials. Each trial ends with a free recall of the words. These responses are recorded on tape. A period of 20 minutes follows the 5th trial in which the patient is engaged in other, nonverbal, tasks. The subject is then requested to recall as many words as possible (i.e. delayed recall), and the test is ended with a recognition trial with registration of RT. Seven parallel versions have been developed.

One of the off-line help programs measures the time it takes the patient to retrieve the words from memory (inter response time, IRT). Another program allows for input of the verbal responses. It subsequently gives information on the learning curve (the increment of responses with the number of trials), the number of errors of repetition (words that are mentioned more than once in a trial), and incorrect words, and learning effects such as the well known primacy and recency effects.

The task was administered to 24 unipolar depressive patients and 26 control subjects, matched for age and education level.

Analysis of the 5 immediate recall scores revealed that the patients had a significantly weaker learning ability than the controls ($p=0.003$). See Figure 3.

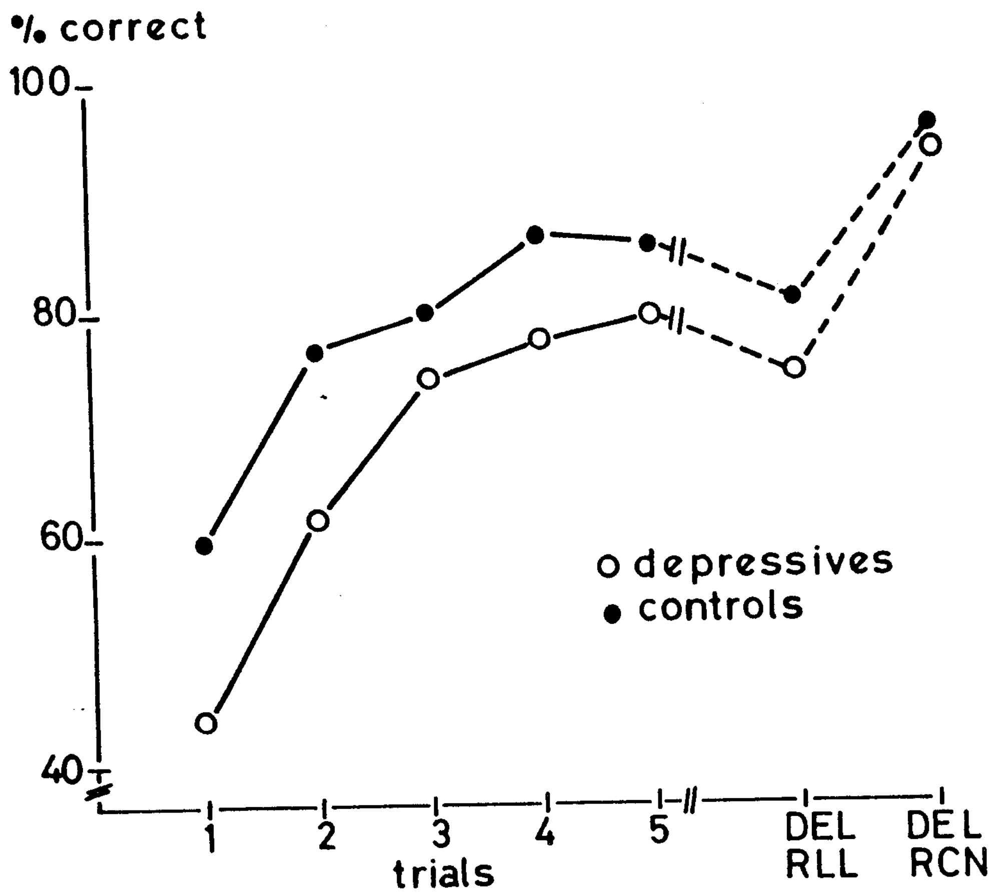

Figure 3. Immediate and delayed free recall (DEL RLL), and delayed recognition (DEL RCN) of a 15 word list presented 5 times to 24 depressive patients and 26 matched controls.

However, there was no difference in delayed recall nor in recognition scores. These results may be taken to indicate that especially the immediate aspects of memory are affected in depression. The patients had a significantly lower speed of recognition than the controls, and also the time to retrieve the words from memory (IRT) was longer (though not significantly). These results are discussed further elsewhere (Brand, 1987). The conclusion may thus be reached that the visual version of the 15 word learning test meets the requirements that were set in section 2.1. It allows for easy administration and recording of latencies. In addition, the stimulus presentation occurs in a standardized way.

4. Application of NEUROPSYCH: Facial recognition test

In the clinic there are some tasks that tap aspects of memory for complex visual scenes (see Lezak, 1983). Unfortunately, these tests are based upon empirical knowledge and have no or only minor theoretical background. They do not enable systematic manipulation of processing stages in memory.

The Sternberg (1975) paradigm, usually applied with alphanumerical material, may be very useful in the study of short term memory processes. The task does allow for dissociation of the cognitive (memory scanning) from perceptual-

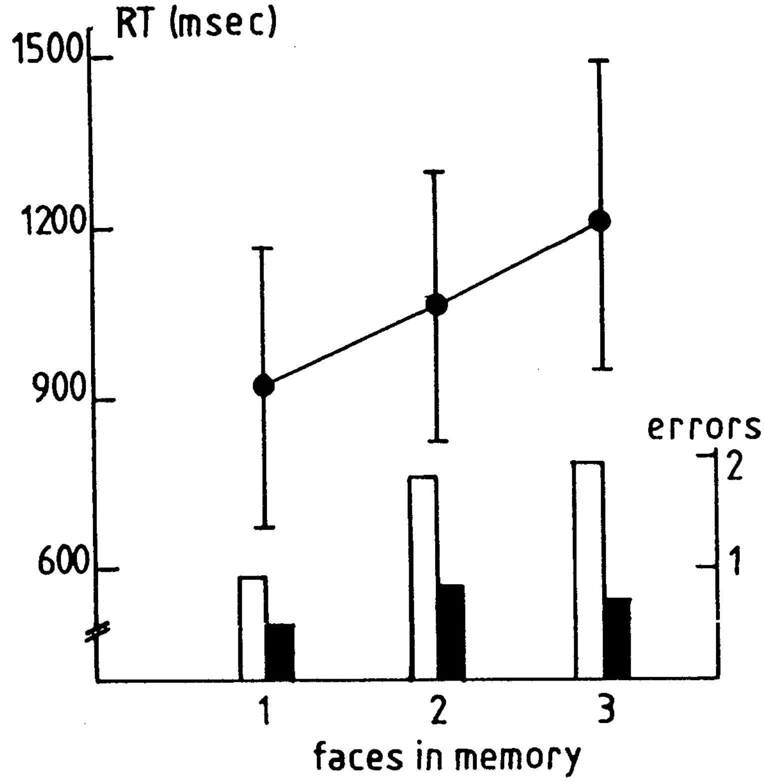

Figure 4. Results on the Facial Recognition task (n=18). Reaction times and errors on positive (open bars) and negative (solid bars) trials as a function of memory load.

motor stages and has potential as a computer test on the field of complex visual perception and memory (Brand, 1987). Photographs of human faces were used as material in the present study. The human face is viewed as one of the most complex instances of nonverbal stimuli. It has been shown (see Sergent & Bindra, 1981) that especially the right hemisphere plays an important role in face recognition.

Normal subjects (n=18) with an age range of 24 - 67 years were used in the present study. The procedure was as follows: the subject is presented 1, 2 or 3 photographs of faces with the instruction to memorize them. A 'test face' is then shown and the subject has to indicate whether this face was one of the memory set or not. The test consists of 42 trials with a 'fresh' memory set at each trial and with a setsize which varies semi-randomly. No face is used in more than one trial. The faces were presented by one of two slide-projectors on a back projection screen and the test face was shown tachistoscopically. The projectors were placed in an adjacent sound-attenuating room.

When the RTs are shown graphically as a function of memory load (see Figure 4), the slope of the function is a measure of the memory scanning time, whereas the intercept with the ordinate is an estimation of both perception and motor output stages. The results (Figure 4) show a linear increase of RT with memory load. This has been shown repeatedly in studies aiming at group comparison (see Sternberg, 1975). There was no statistical difference between RT on positive and negative trials (these data were accordingly combined in the figure), but more errors were made on positive than on negative trials ($p=0.009$).

Figure 5 shows that the results from most individual cases are very reliable according to the linearity coefficients (correlation between RT and size of memory set). That is, 72 % of the subjects involved had a correlation higher

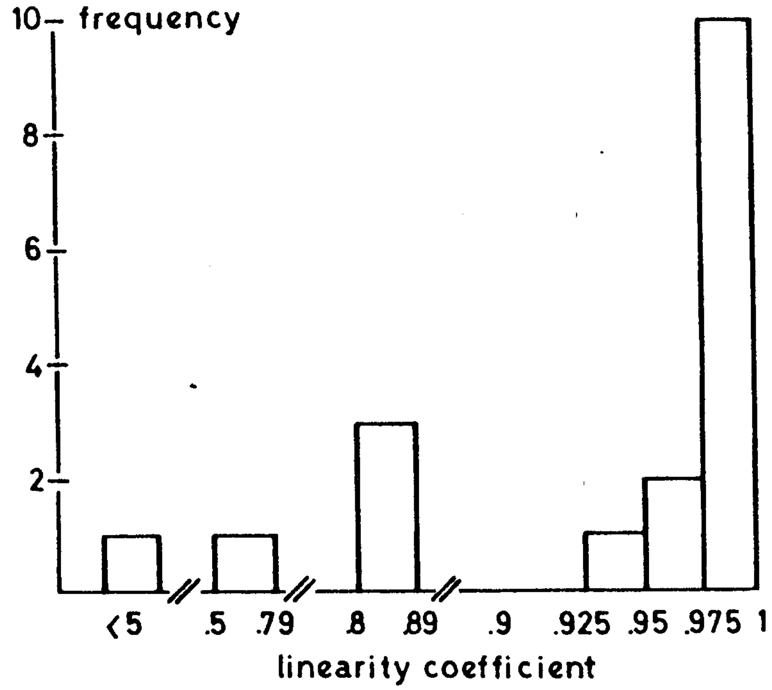

Figure 5. Frequency distribution of the linearity coefficients obtained with the Facial Recognition Test.

than 0.94.

The conclusion may be reached that the test enables the processing of complex nonverbal material and may show reliable results even in individual cases. It thus satisfies the boundary conditions that were set in section 2.1.

5. Discussion

NEUROPSYCH has proven its value and meets the requirements that have been set for use in the clinic. It may be concluded that it provides an efficient and refined technique for the measurement of different cognitive entities. In addition, administration and registration of response latencies has been shown to be easy. These findings add to the notion that the combination of methods from behavioral neurology, psychometric methods and the information processing approach is an optimal way to obtain an estimation of the cognitive state of patients with brain-dysfunctions (Jolles, 1985). As such, computer-based methodology may enable the measurement of cognitive functions that cannot be evaluated by the more traditional psychometric tests. Neuropsychological assessment may thus benefit from the use of these techniques. The development and clinical evaluation is therefore an important topic.

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